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SIR WM. THOMSON AND ELECTRIC LIGHTING.

BY GEORGE WESTINGHOUSE, JR., PRESIDENT OF THE WESTINGHOUSE ELECTRIC COMPANY.

THE article on "Electric Lighting and Public Safety" by Sir William Thomson in the February number of the NORTH AMERICAN REVIEW possesses unusual interest by reason of its clear and forcible presentation of the precautions which have been adopted by the authorities in Great Britain to secure to the public the utmost possible degree of safety from electric currents conveyed by overhead conductors, and especially because it furnishes an adequate explanation of the unusual number of difficulties and fatalities which have occurred in connection with such conductors in the city of New York and in certain other localities, where the attempted municipal regulation of electric circuits has been of such a character as to aggravate tenfold the very evils it has been designed to remove. Of the points discussed in this article, the one which should receive the most careful attention at the present time, on account of its bearing upon the immediate future of the electric industries in the United States, is that which has reference to the recent action of the authorities in Great Britain concerning the granting of "provisional orders" to companies proposing to undertake the electric lighting of municipalities and municipal districts. It is only necessary for my purpose to quote his conclusion, which is as follows:

> "It may be considered, indeed, as now definitely resolved that the distribution of electric energy for light and power in the towns of the United Kingdom shall be by underground conductors, and plans for carrying this into effect safely and economically are engaging the anxious consideration of electrical engineers."

An examination of the Board of Trade regulations appended to Sir William's article discloses one fact of controlling importance, and that is that not only must electric light and power conductors, even when safely and securely erected and perfectly maintained, be surrounded with costly safeguards, but every telegraph, telephone, or other wire must be equally well protected, of course at a corresponding expense. In localities having an extensive network of these wires, an attempt to secure safety by the rigid enforcement of the Board of Trade regulations may well cause Sir William to remark that "the fulfilment of these rules can, indeed, be made practically certain. *But at what cost?*"

In view of the experience already had in this country, it may be taken for granted that no sane person would now undertake to erect aërial electric light and power wires in any locality in which telegraph or telephone wires were numerous, if compelled to comply strictly with the regulations of the Board of Trade. In fact, the evident determination of the authorities in Great Britain to virtually prohibit the use of aërial electric light and power wires in cities may be construed as a final determination that the problem of safe electrical distribution can be solved only by resorting to the use of underground conductors. One might almost go so far as to say that these regulations are in themselves sufficient, by rendering aërial electrical distribution in a commercial sense impossible, to do away with the necessity for their existence.

The enormous pecuniary damages which, in obedience to public clamor, have been inflicted upon those electric-lighting companies in New York city having their conductors overhead, mainly because of ill-secured and abandoned telegraph and telephone wires which persisted in falling down upon them, have sufficiently emphasized the fact that it is not worth while for any electric company doing business in that city to give further consideration to the problem of distribution for light and power service other than by means of underground conductors. Hence it will appear that much remains to be done towards the solution of the real problem; the necessary regulations, and even in a great measure the considerations on which these are to be based, are yet to be formulated. Instead, therefore, of devoting further space to the discussion of the Board of Trade regulations, it would seem more desirable to consider how we may guard against some of the difficulties and dangers which are liable to occur in the distribution of electric light and power currents by means of underground mains; not unmindful of the fact that the constant march of improvement may render regulations which are ample and sufficient for to-day totally inadequate or even worse than useless for the conditions of to-morrow.

Before undertaking to frame specific regulations for guarding against the danger which is to be apprehended from electric currents traversing underground conductors, it is important to ascertain with as much accuracy as possible its character and extent. So far as concerns the consumers of electric energy in any form, or the general public, the danger may obviously be divided into two classes: first, the risk to persons from physical contact with a conductor charged with electricity at a high tension or pressure; and, second, the risk from fire originating from the heat-energy of the electric current under certain conditions. Concerning the first class Sir William Thomson says: "I may remark that 100 volts in the house is perfectly safe to the user, whether the current be alternating or continuous, as is proved by large and varied experience in England"; hence the only precaution necessary to guard against injury is to prevent the possibility of contact with a conductor charged with a high-tension current.

Before proceeding to discuss the danger from fire, it is, perhaps, desirable to give the reader some idea of the difference in this respect between the behavior of the alternating and the continuous current. It is now quite generally understood that in the generation of electricity for electric lighting and similar purposes a coil of wire with united ends is caused to approach a magnet, by which operation a pulsation of electricity flowing in a definite direction is produced in the wire; and when the coil is withdrawn from the magnet, another similar pulsation is produced, but this time in the opposite direction. The repetition of this operation produces a succession of pulsations, alternating in direction, which is termed an alternating current; and in what is known as the alternating system of distribution these natural currents are used in the distributing mains directly, as they are produced by the generator. The production of what is known as a continuous current involves the changing of every alternate pulsation by a complicated mechanical contrivance called the commutator, which, through two sets of brushes,—one set taking all of the positive currents, and the other all of the negative,—causes the successive pulsations all to flow in the same direction, constituting what is technically termed a direct current and usually spoken of as a continuous current. This current is similar in character to that generated by the well-known chemical batteries.

Although the alternating current is really the natural current, and has been known as such for half a century, yet it is only within a very few years that the appliances for its utilization have been brought to sufficient perfection to be of practical utility, and it is only still more recently that its inherent advantages over the direct current for all purposes of electrical distribution are becoming recognized and appreciated. The fundamental and all-important advantage, in this respect, which the alternating current possesses over the direct current resides in the fact that an alternating current, when made to traverse a coil of wire, is capable of inducing or creating in an independent coil of wire in the neighborhood of the first coil a similar alternating current of equal energy, but capable of having its pressure or its quantity modified to any required extent—a result which the continuous current is utterly incapable of producing.

This important characteristic of the alternating current renders it possible to generate an electrical energy of any desired low pressure in a local system of conductors situated at any point, yet having no electrical connection, of any character whatever, with the main conductors. By means of an apparatus known as a converter or transformer, which consists of little else than a mass of iron and copper inclosed in an iron box, the electrical energy traversing the main conductors is converted into magnetism—a perfectly inert and harmless form of energy, capable of producing neither heat nor shock, nor of being appreciated by any of our senses—and this is reconverted into electrical energy for local distribution. The interposition of this absolutely harmless form of energy as one link in the chain of effects secures, under proper and well-understood conditions, an absolute safety from fire which it is impossible to obtain when the continuous current is used, for the reason that the latter necessarily involves an unbroken and direct electrical connection between the distributing and the consumption circuits. That the distribution of electricity by alternating currents of high tension, the transformation of the same by converters into low-tension currents, and the absolute disconnection of the two systems of conductors, are becoming generally recognized as features of controlling importance, is abundantly testified to by the almost universal adoption of these characteristics in the modern electric-lighting plants in Great Britain, continental Europe, and South America, while in the United States more than four-fifths of the central-station plants which have been erected during the past year are of the alternating system.

The recent distressing calamity in Washington, which resulted in the death of the wife and daughter of Secretary Tracy, again enforces the lesson that of all the dangers which confront us none are so imminent and none so difficult to guard against as those which arise from fire ; and it is scarcely necessary to say that the continual apprehension that a fire may originate at any moment from wires connected to underground electric mains may become almost unbearable. We are but too frequently reminded of this danger by such occurrences as the recent destructive conflagration in Boston, which is believed to have resulted from an electric current, or other fires in New York city during the past few months due to the same cause, among which may be mentioned the sudden and complete destruction of the Pearl-Street electric-lighting station, which is understood to have been caused by an imperfection in the low-tension underground mains receiving their supply therefrom. These disasters, as well as the incident related in this REVIEW by Mr. Edison, who stated that a contact between the mains of his underground circuits, at the corner of William and Wall Streets, resulted in burning up the iron and copper of the conductors, and the reduction of the paving-stones for several feet around to a molten mass, show that it has become imperatively necessary to reconsider and revise the present rules and regulations, and to adopt such new ones as may be found necessary to remove this omnipresent danger from fire caused by electric currents.

In considering this source of danger it should be borne in mind that electrical fires are results which are due directly to the quantity or volume, and not to the tension or pressure, of the current. The welding together of massive iron bars is quickly and perfectly accomplished with an electrical pressure of only one volt, although the volume of current is, of course, enormous. In the case cited by Mr. Edison, had the same electrical energy been conveyed at a pressure of 2,000 volts, instead of 110, no such destructive development of heat could have been possible ; or had the mains of the system referred to by him been subdivided, instead of being interconnected into one enormous net-work similar to that of the gas-pipe system, the volume of current at any one point would have been wholly inadequate to produce effects like those described. It scarcely need be demonstrated that so long as vast systems of electric mains continue to be interconnected underground, and all the electricity of low tension and great quantity that can be supplied by engines of 1,000 to 2,000 horse-power is poured into them, so long may we confidently expect from time to time these destructive conflagrations originating in underground conduits. No more effective plan to insure great destruction whenever a contact takes place between two wires could possibly be devised than the interconnection of all the mains, for the reason that it enables the aggregate energy of the whole station to be suddenly concentrated from every direction upon some one point; and this is equally true whether the contact occurs in the street or within the walls of a building.

A very important, but little-understood, source of danger from fire arises from the leakage of current from underground mains, which is taken up by water- or gas-pipes. Where the amount of wire interconnected is large, this leakage is sufficient to light a considerable number of lamps as effectively as if they were attached to the wires in the usual manner. If, therefore, any wire having a direct connection with an underground main is accidentally brought into contact with a gas- or water-pipe, a fire may be instantly started in a place wholly concealed from observation; or if the electric wires are laid underneath a floor, and their insulation is defective at any point, even the solution of soap and water used in scrubbing may establish a path for the electric current, which will be followed in a few minutes by a well-developed fire. As the wires in buildings become older, their insulation is likely to become more and more defective, and with the lapse of time wires once well insulated, especially in situations in which inspection is difficult; will, when in connection with an imperfect system of distribution, become sources of danger.

It is conceded by all familiar with these matters that contact with a conductor charged with an electrical pressure of one hundred volts or less is not in the least dangerous to persons, whether the current be direct or alternating; but so far as the fire-risk in buildings is concerned, it make a vast difference whether a pressure of one hundred or of fifty volts is used. In experiments which have been made expressly to determine this difference, it was found that a fire could be easily started between two wires with one hundred volts of direct current by the moisture from such water as is commonly used for cleansing, while it was quite impossible to do so with a pressure of fifty volts of alternating current. It would, therefore, seem to follow from these considerations that the abandonment of the practice of connecting the street mains directly with the wires in buildings will remove at once and absolutely the most imminent fire-risk which otherwise is ever present; while by taking one step further, and reducing the pressure on the wires in buildings to, say, fifty volts, we shall so diminish the possibilities of the occurrence of a fire that there can no longer be any ground for the slightest apprehension on this score in the minds of those enjoying the benefits of the electric current supplied from underground mains.

The sufficiency of transformers or converters to absolutely prevent electrical connection between the street mains and the wires within buildings, has sometimes been questioned. An investigation has shown that in the converters constructed by some manufacturers the coil connected to the high-tension mains is wound upon a form or bobbin, and the second coil connected to the house wires is then wound directly upon this first coil. It is not strange that with converters of this construction contacts have sometimes been formed between the high-tension and low-tension wires, from which, at least in some instances, serious results have followed. In a properly-constructed converter a wholly different course is pursued; the two coils are wound separately upon separate forms, each layer of each coil being effectually insulated from all others, and when completed each coil is carefully wrapped with insulating material, after which they are placed in position, but at such a distance apart that it is impossible for the current to pass from one coil to the other, even if the insulation were not perfect. Many thousands of such converters have been put in use by the company which first introduced the alternating system in this country, and there has never yet been a single instance recorded of an accidental connection between the high- and low-tension coil. All converters are, or should be, placed in fireproof situations at the point where the wires from the street main enter the building, and accessible only to authorized persons. Under these conditions it is evident that it will be impossible for any person within the building to come in contact with wires carrying a greater pressure than fifty or one hundred volts. It is scarcely necessary to point out that, so soon as the requirements for safety are fully understood, the use of insufficient and dangerous forms of converters or transformers will be prohibited.

One point which should not be overlooked, while considering the question of electrical distribution, is that with reference to the space now available in our city streets for underground work. One of the ducts in the subways as now constructed in New York city will accommodate a pair of wires capable of carrying, say, 100 ampères of current. If the pressure were to be limited to 200 volts, as some have proposed, such a pair of wires would supply in ordinary practice only 400 incandescent lamps, and those must be within a limited distance from the station; but if the pressure were to be increased to 2,000 volts, these same wires would supply no less than 4,000 incandescent lamps; and, moreover, these might be at a distance from the station many times greater. Hence with the low-pressure current it will require at least ten ducts to provide for the same amount of lighting over a small area as could be effected with one duct at a pressure of 2,000 volts, and this is true even in an extensive distribution.

The immediate dangers from underground conductors are of two kinds; one arising from contacts which may occur between the electric wires, and the other from explosions of gas which may accumulate within the manholes. The frequency of the first will depend upon the number of wires, or, speaking more accurately, upon the quantity of current carried; while the latter are more liable to occur where there are many conduits and manholes. It seems clear, therefore, if by using high-tension currents the extent and area of the main conduits can be reduced to one-tenth of those required for low pressure, that there is every reason to expect that, when all the advantages are fully understood and appreciated, the use of a high-tension main current will be enforced purely from considerations of safety, without reference to economy.

Concerning the violent explosions of mixed air and gas in the subways and manholes, it has been observed in New York that they are quite as liable to occur in cases where the wires are used exclusively for the telegraph or telephone service, or for low-tension currents, as where they are used for high-tension currents. This is not surprising, as an explosive mixture will ignite quite as readily from a spark of half a volt as from 100 or 1,000 volts' pressure. Experience has shown, however, that no explosions have occurred when the manholes have been properly ventilated.

If electrical fires can be absolutely guarded against by a complete electrical separation between the street-main wires and those within buildings, with a limitation of the pressure in the last-named to fifty volts, and if such conditions can be readily complied with, may it not be advantageous to make those conditions compulsory ? If conduits, subways, and even sections of street pavement can be destroyed by large-quantity currents, ought not the quantity carried by each conductor to be limited ? If the practice of interconnecting all the mains in a district is fraught with danger, ought not the practice to be abated ? To these questions my answer is : The system of alternating currents and converters admits of these measures of safety : namely, an absolute electrical separation of the street mains from the wires in all buildings ; the reduction of the pressure of the current to fifty volts within all buildings ; the limitation of the quantity of current carried by street mains ; the running of each pair directly from the station without interconnection in the streets, thus securing the highest degree of safety, irrespective of the economical advantages, which are neither few nor unimportant. It is much to be desired, in the interest of the public, that a thorough investigation of this whole subject should be made at the present time by competent and disinterested authorities. It is my own belief that such an investigation would lead to the adoption, among others, of regulations substantially as follows :

1. No direct electrical connection shall be permitted between street mains and wires within buildings for either light or power.
2. The electrical pressure on the wires within buildings shall not be permitted to exceed one hundred volts.
3. Each pair of street mains shall be limited in load or volume to an amount not exceeding one hundred ampères, and every such wire shall be provided at the generating station with a device which will automatically disrupt the circuit in the event of a sudden increase above the authorized load.
4. Within buildings, the load for any one pair of wires shall not exceed that required to supply one hundred sixteen-candle-power lamps.

To these fundamental regulations it is, of course, apparent that many subsidiary ones must be added ; but it is certain that such a system as that above outlined may be made to conform to such regulations as I have indicated, not only without additional expense, but with a great and positive gain in economy both in construction and operation.

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